Hydrologic Model Review

CBRFC Stakeholder Forum

October 20, 2015

Salt Lake City, UT

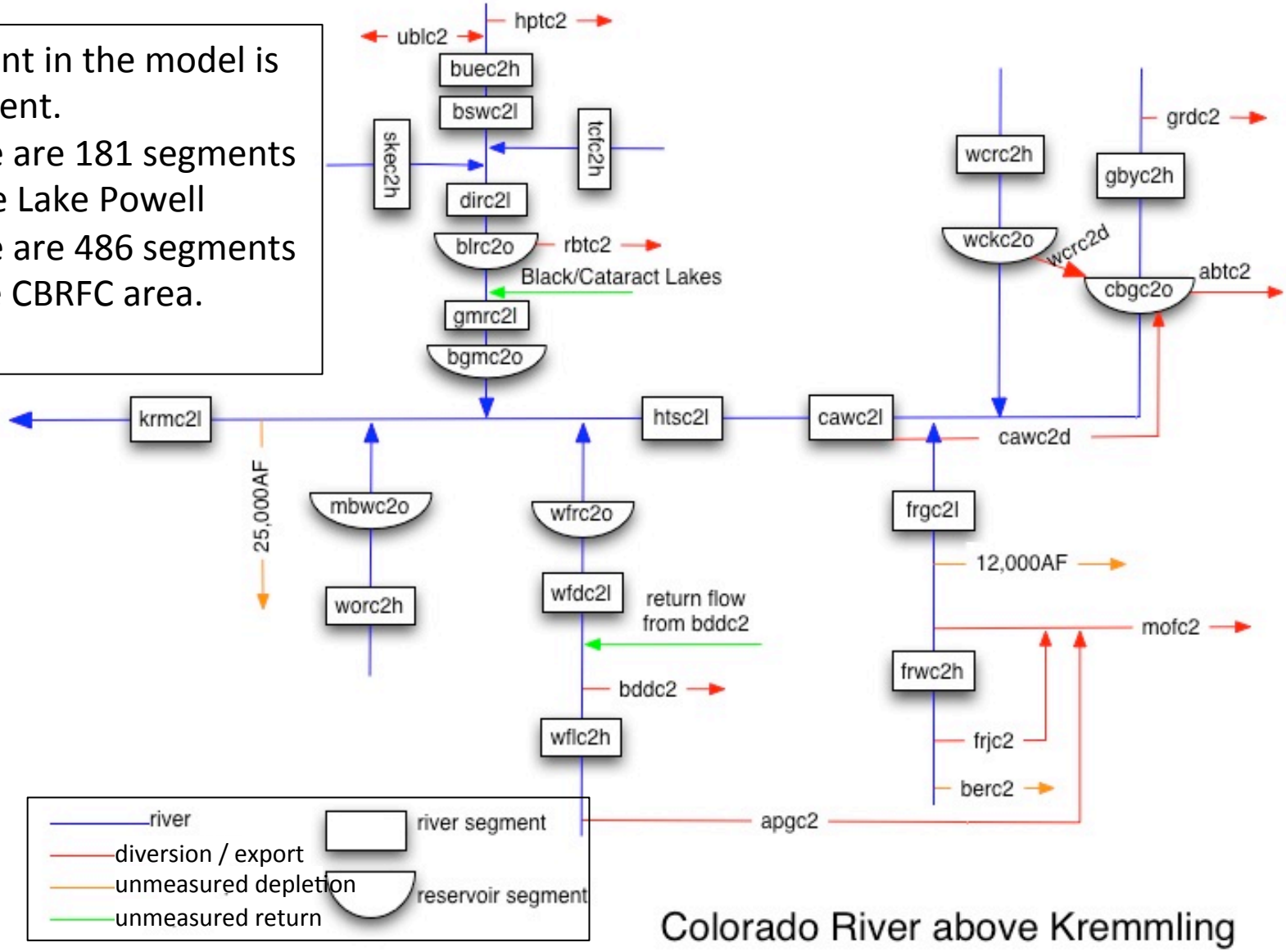
CBRFC Model Description

- Continuous
  - meant to be run all the time, not just during events.
- Conceptual
  - physically based, but uses parameters in place of hard-to-get data.
- Lumped
  - uses mean areal inputs; not distributed.
- Main components:
  - SAC-SMA – soil moisture accounting model for generating runoff
  - SNOW-17 – temperature index model for snow accumulation and ablation
- Calibrated using 1981 – 2010 data

CBRFC Model Setup

Each river point in the model is called a segment.

- There are 181 segments above Lake Powell
- There are 486 segments in the CBRFC area.



CBRFC Model Setup

- Segments are calibrated to the *Unregulated Flow*.
  - *Measured* diversions, imports, exports, and reservoir regulation are accounted for to approximate natural flow.
    - Observations are available in real-time
  - *Unmeasured* depletions and return flows are not accounted for and why this is not the same as 'Natural Flow'.
    - Usually known, unmeasured irrigation.
    - Derived by CBRFC during calibration using a model that is a function of irrigated acres and temperature.

$Q_u = Q_o + D + E - I + \Delta S$

Q_u = unregulated flow

Q_o = observed/measured flow

D = measured diversion

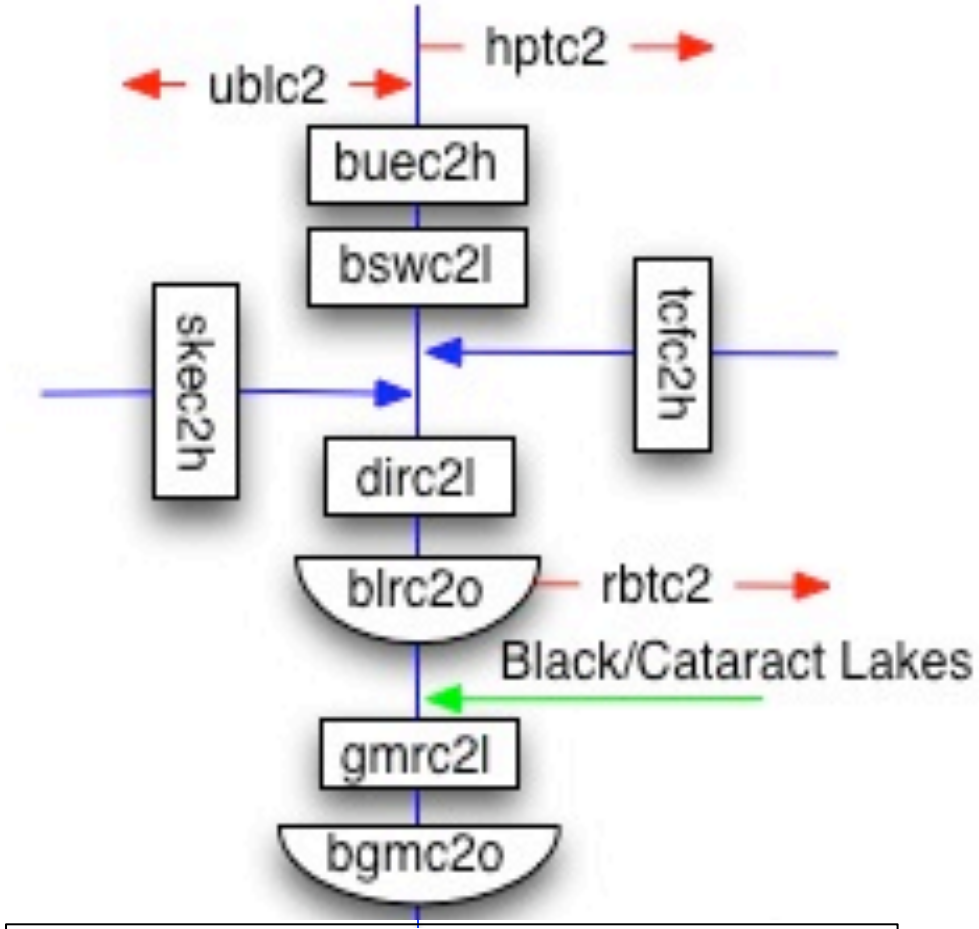
E = measured transbasin/transmountain export

I = measured import

ΔS = change in reservoir storage

CBRFC Model Setup

Blue River Basin



$gmrc2_{unreg}$ =

$gmrc2_{obs}$	(Green Mtn Res inflow)
+ hptc2	(Hoosier Pass Tunnel)
± ublc2	(Upper Blue Res operations)
+ rbtc2	(Roberts Tunnel)
+ Δblrc2	(Dillon Res storage)

During calibration always check that

Unreg Sim ≈ Unreg Flow

at each segment as we move downstream.

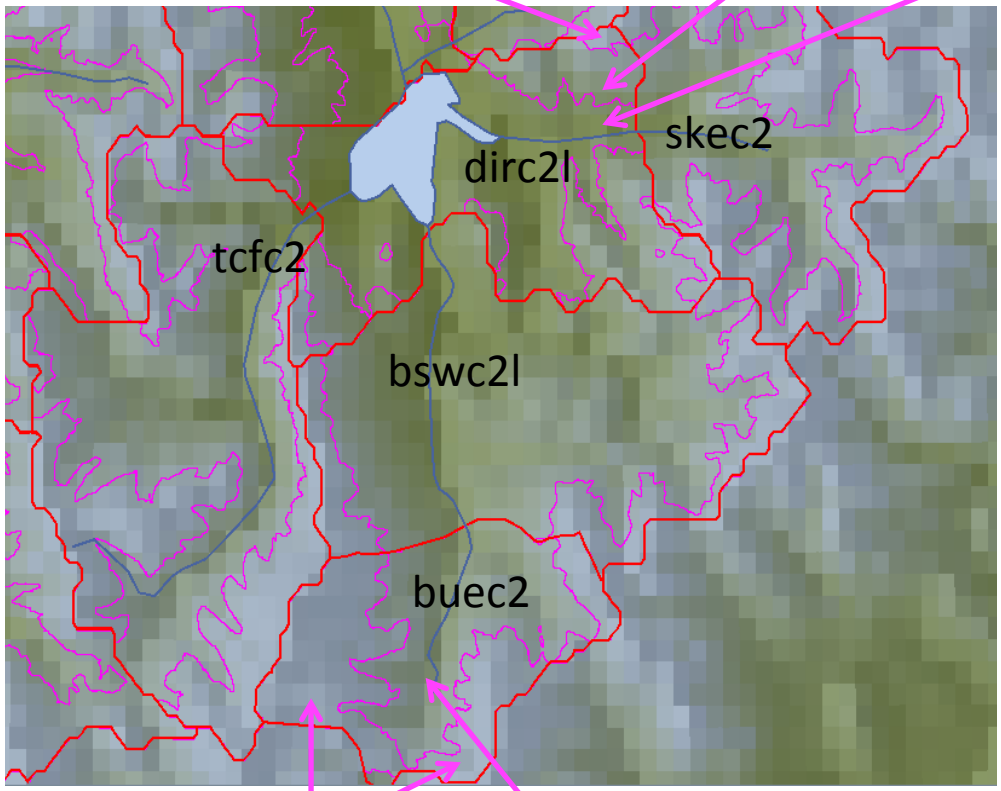
$gmrc2_{sim} \approx gmrc2_{unreg}$

CBRFC Model Setup

Upper Area
11,500 ft – 13,753 ft
3 mi^2

Middle Area
10,000 ft – 11,500 ft
34 mi^2

Lower Area
8927ft – 10,000 ft
23 mi^2



Each segment is broken into 2-3 subareas by elevation.

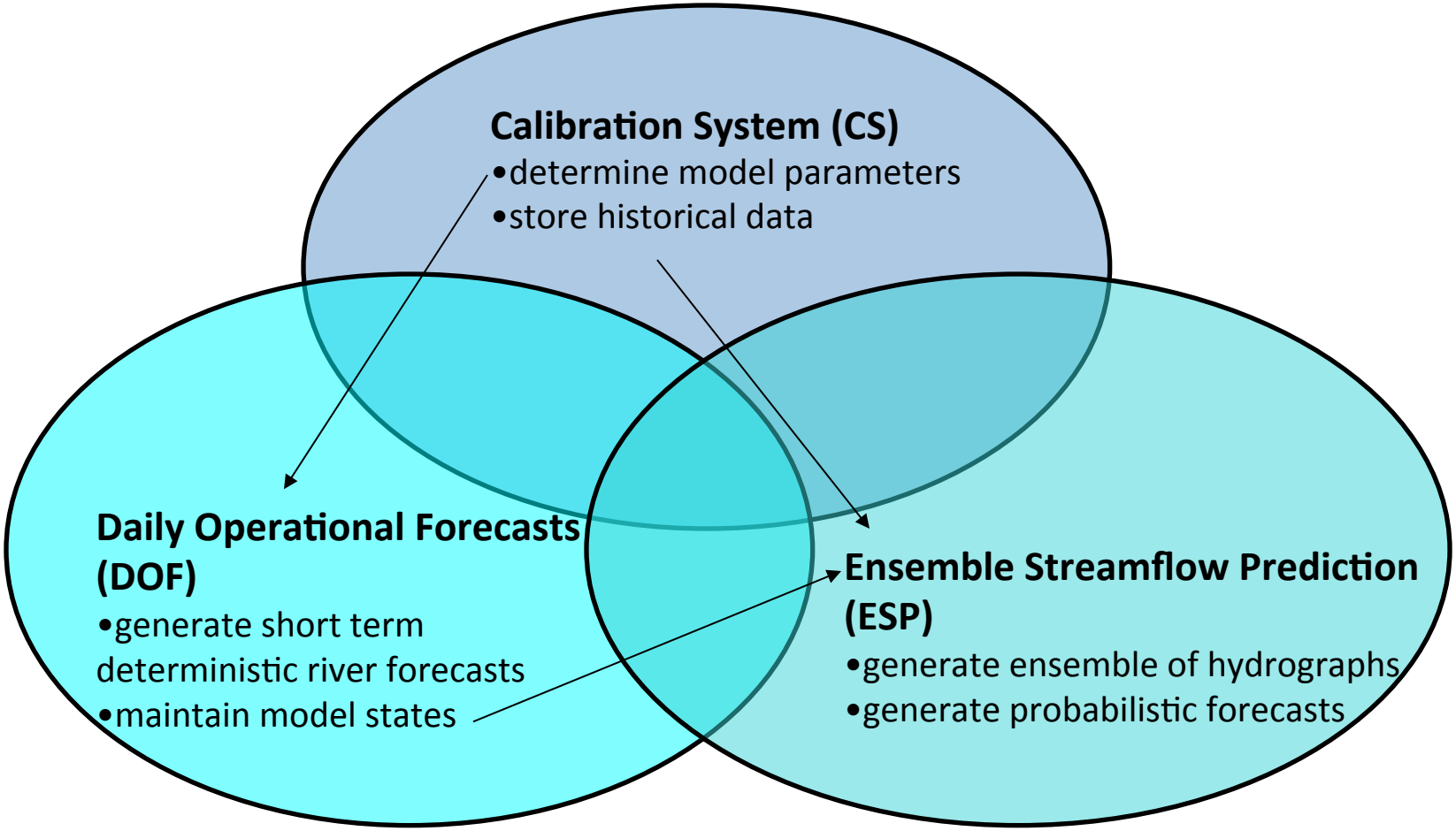
- These subareas should have similar soil, land cover, and snow accumulation/melt characteristics.
- Because it is a lumped model each of these subareas is represented by a single (mean areal) point for precipitation and temperature.

Upper Area
11,500 ft – 13,690 ft
21 mi^2

Lower Area
9980 ft – 11,500 ft
21 mi^2

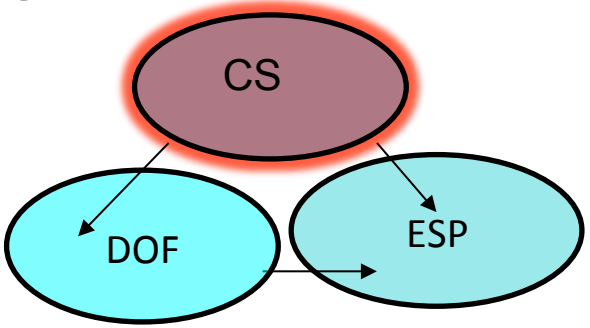
NWS River Forecast Model

Composed of three major interrelated components.



Calibration System (CS)

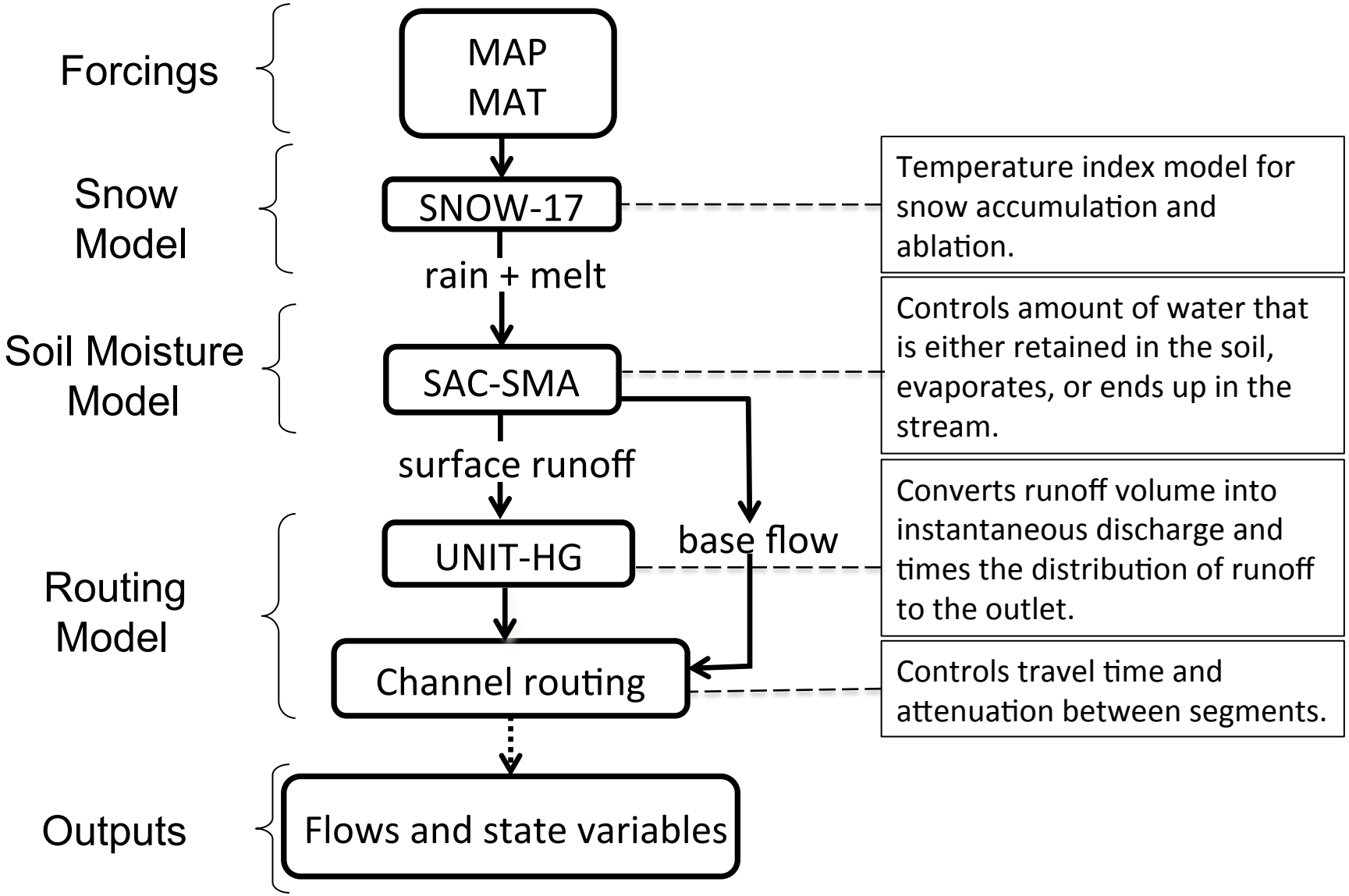
- Store historical precipitation, temperature and flow time series for the basin
- Choose from a variety of sub-models and processes
  - Snow model
  - Soil moisture model
  - Unit Hydrograph
  - Channel routing
  - Reservoir operations
- Determine the optimal set of parameters for each model, for each sub-area to best simulate *unregulated* flow



Calibration – Basics

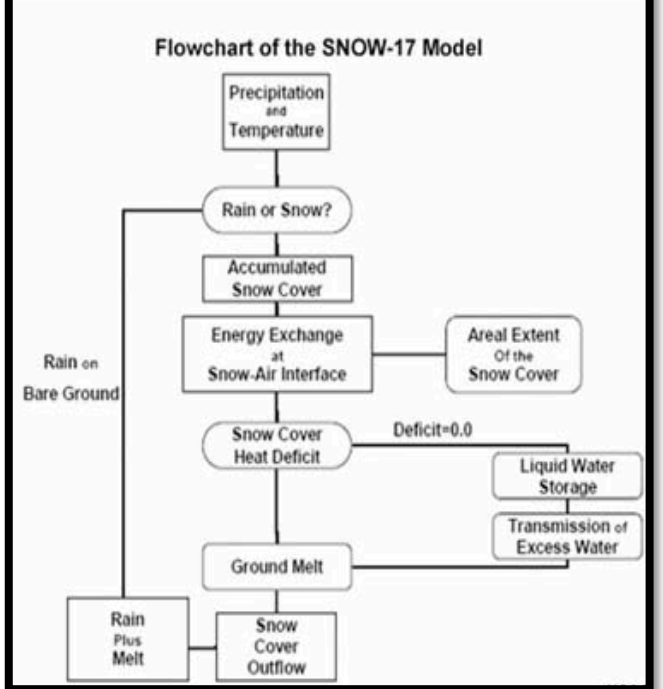
- Evaporation is determined through water balance and is regionalized.
  - Based on PRISM data sets.
- Forced by 30 years (1981-2010) of 6 hourly precipitation and temperature.
  - Mean Areal Precipitation (MAP) for each subarea is calculated using pre-determined station weights.
    - Use precipitation stations that (hopefully) have similar characteristics to that area.
    - Weights are chosen to guarantee water balance in each area.
  - Mean Areal Temperature (MAT) for each subarea represents the mid-point elevation.
    - Nearby stations (climatologies known) are used to calculate the temperature of the MAT (climatology calculated using climatologies of the nearby stations).
  - Operationally MAP and MAT are calculated in a similar way to ensure our forecasts will have similar quality/characteristics to 30 years of calibration.

Calibration – Basics

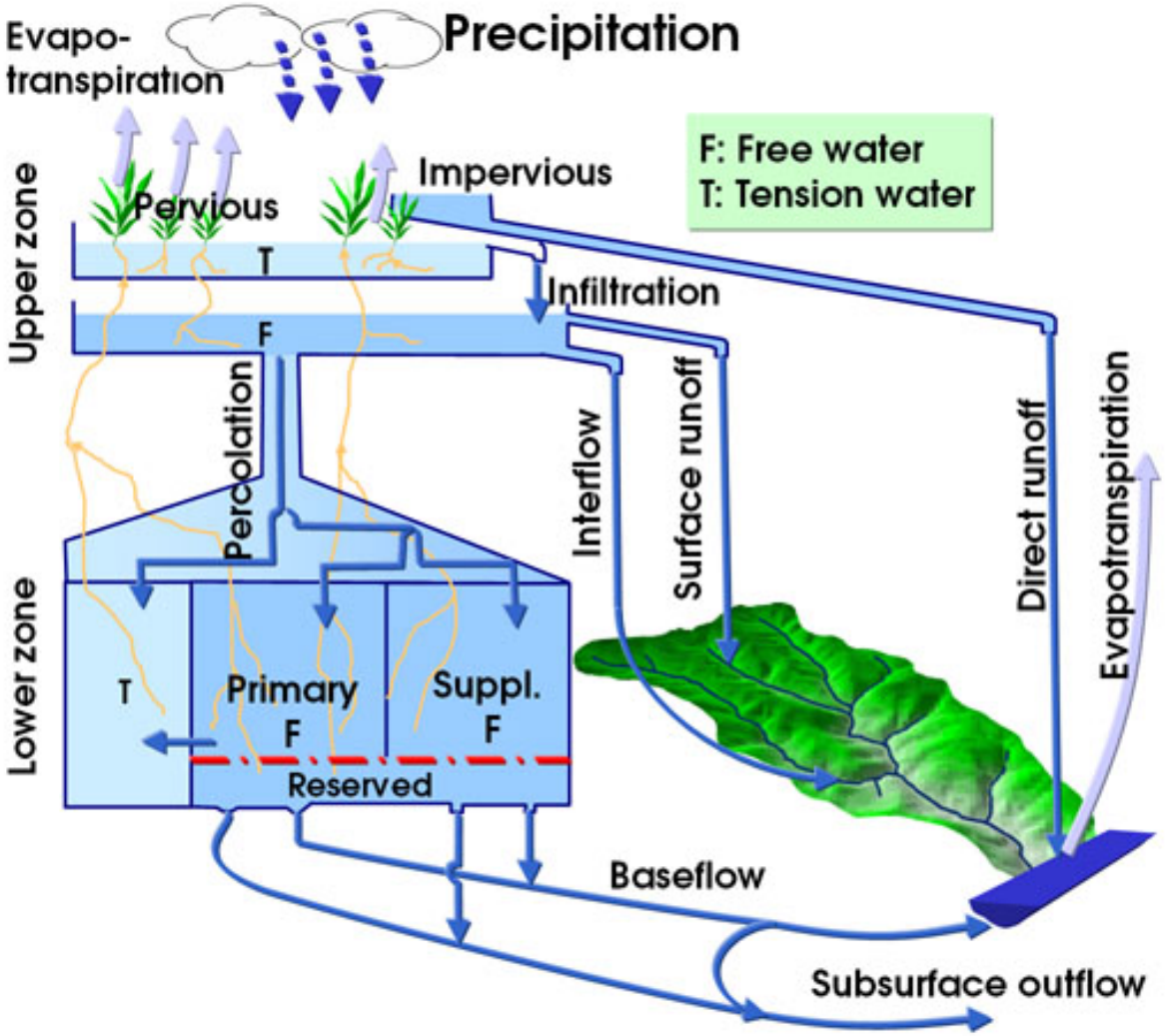


Snow and Soil Models

SNOW-17



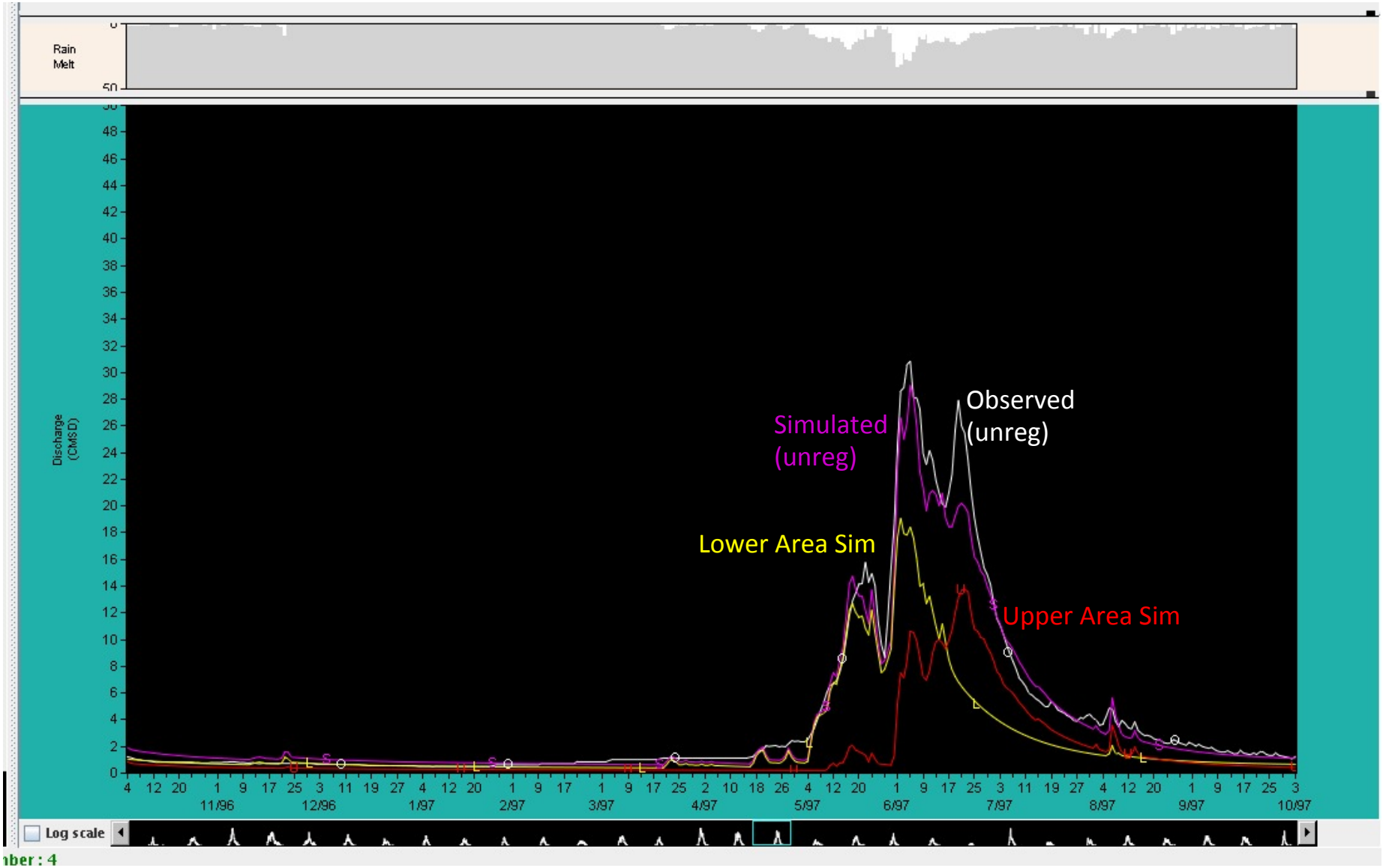
SAC-SMA



Calibration – Parameters

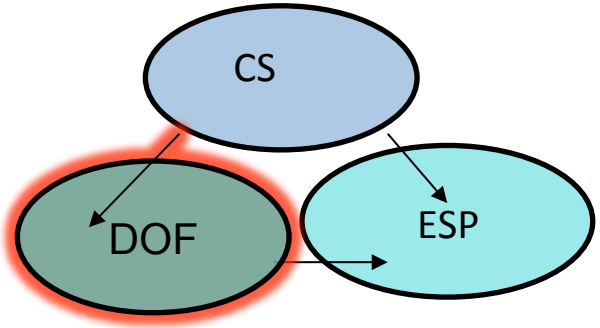
- Determine calibration parameters for each subarea
  - SNOW-17
    - 5 Major
      - Snow Correction Factor, Max and Min Melt Factors, Wind Function, Snow Cover Index, Areal Depletion Curve
    - 5 Minor
      - Temperature indexes and minor melt parameters
  - SAC-SMA
    - 11 Major
      - Tank sizes (5) and rates of drainage (interflow, percolation)
    - 5 Minor
      - Impervious area, Riparian Vegetation effects

Calibration – Results

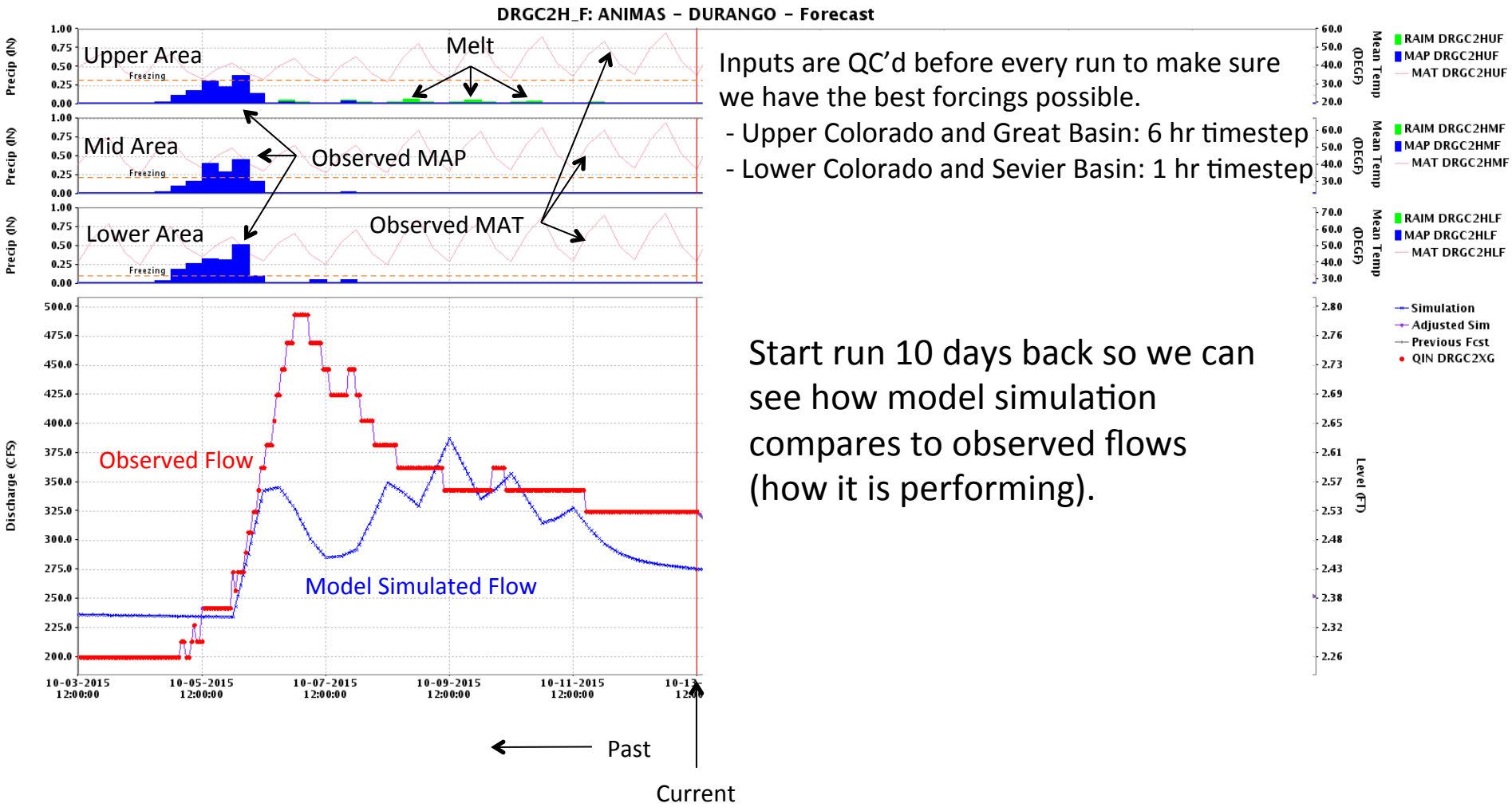


Daily Operational Forecast(DOF)

- Quality Controlled Inputs
  - Observed precipitation, temperature, and streamflow
  - Forecast precipitation (5 days) and temperature (10 days)
- Model adjusted by forecasters in real time
- Keeps track of model states, including soil moisture and snowpack
- Can be run multiple times per day so there is continual quality control, updating and adjusting
- Outputs 10 day *regulated* deterministic streamflow forecast



Daily Operational Forecasts

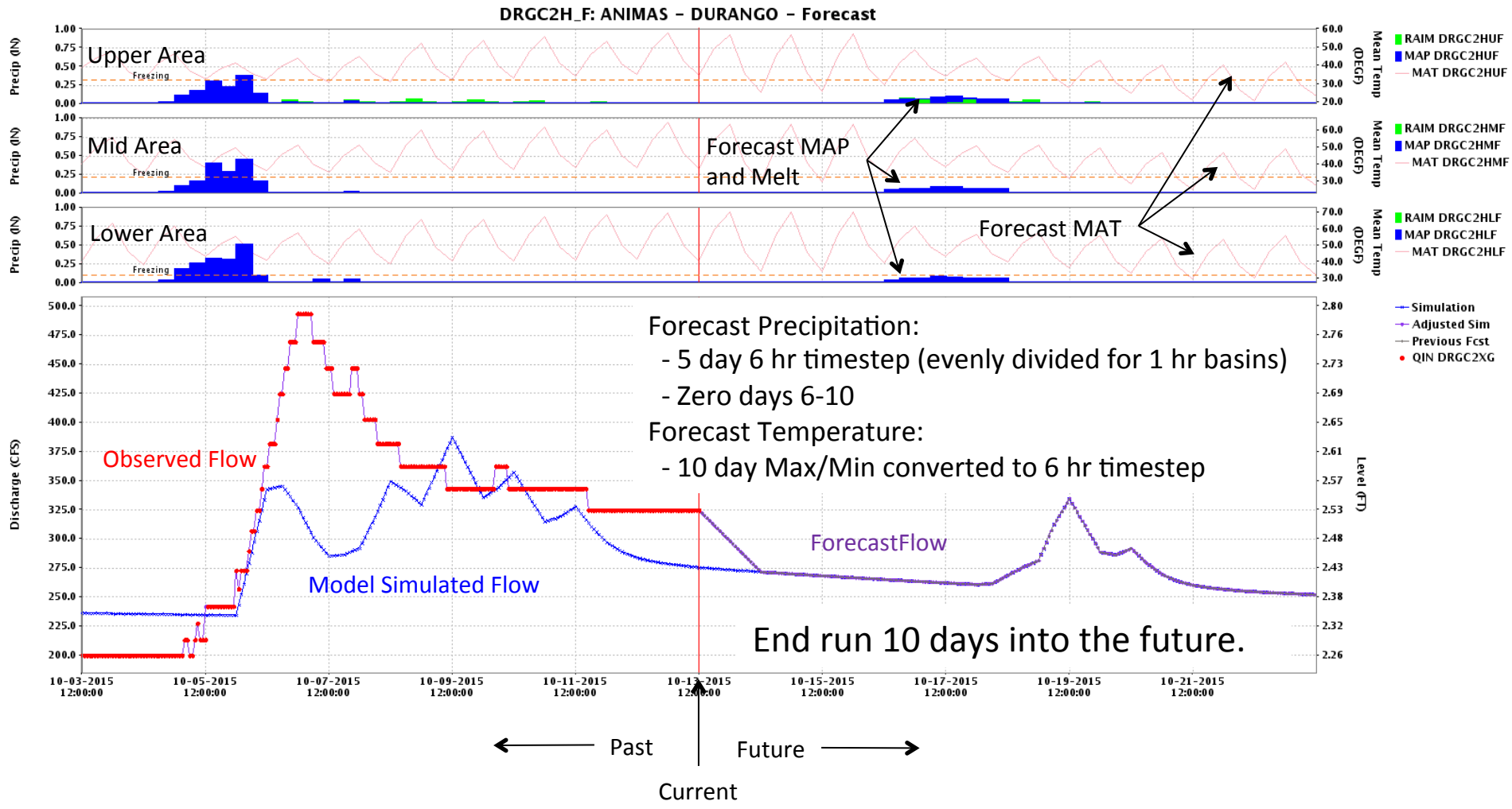


Inputs are QC'd before every run to make sure we have the best forcings possible.

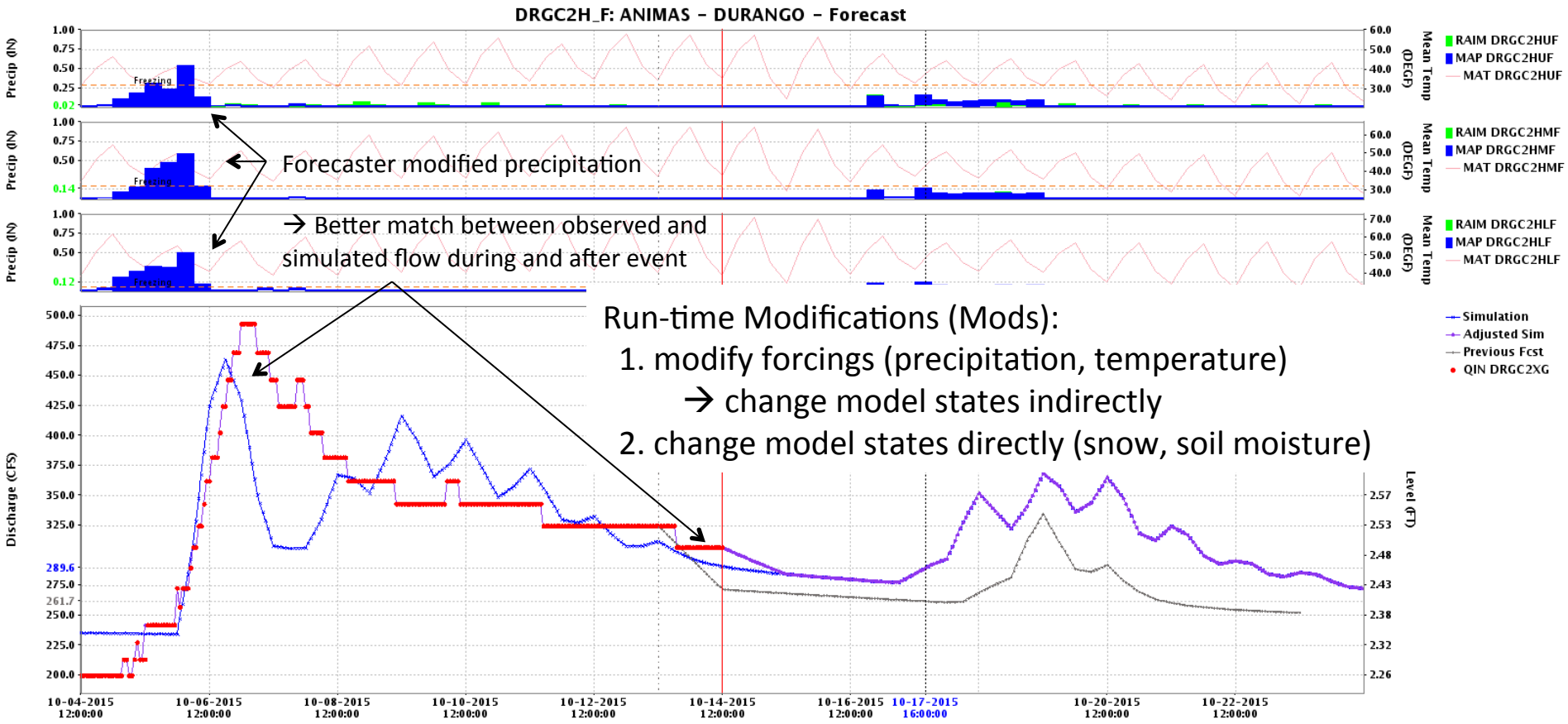
- Upper Colorado and Great Basin: 6 hr timestep
- Lower Colorado and Sevier Basin: 1 hr timestep

Start run 10 days back so we can see how model simulation compares to observed flows (how it is performing).

Daily Operational Forecasts



Daily Operational Forecasts

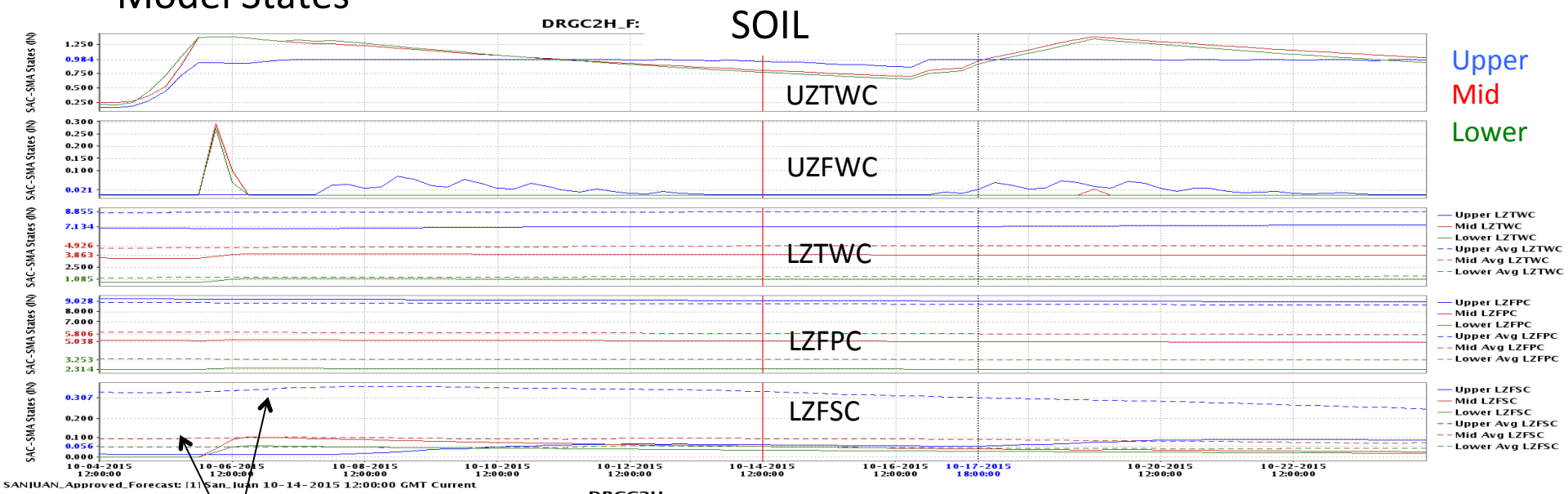


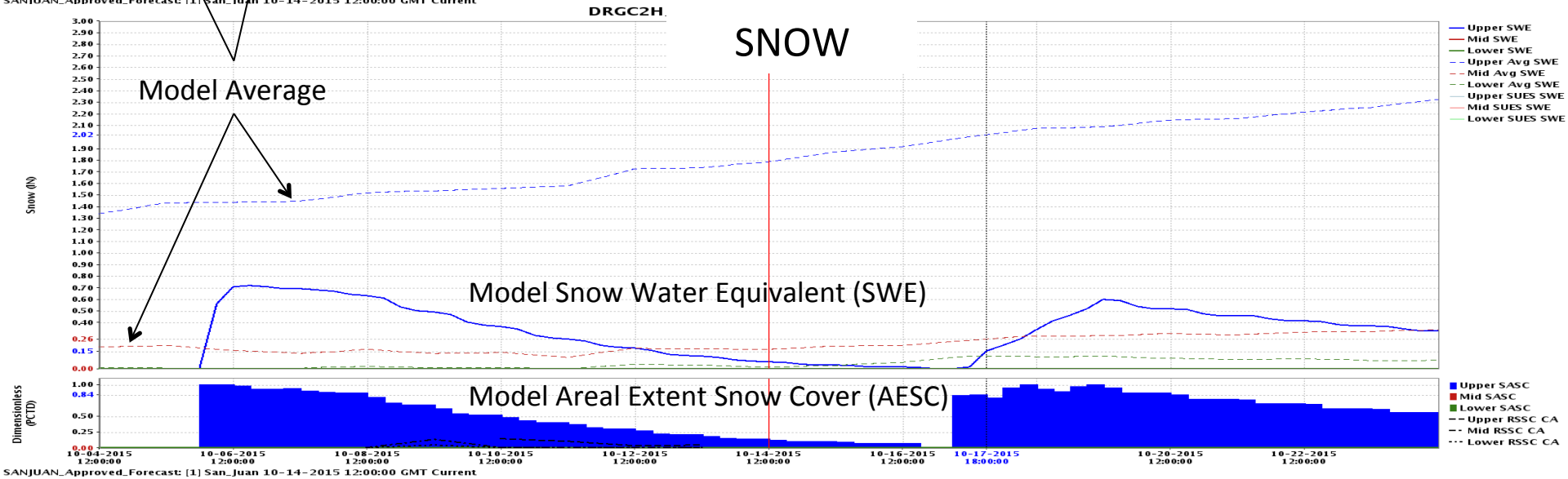
CBRFC Modification philosophy:

Modifications must be reasonable and make sense – don't want to do whatever is necessary to make it match exactly. This gives us a better chance of simulating the next event correctly.

Daily Operational Forecasts

Model States





Operations
Initial Conditions – Soil Moisture

LZFPC (baseflow or free water)

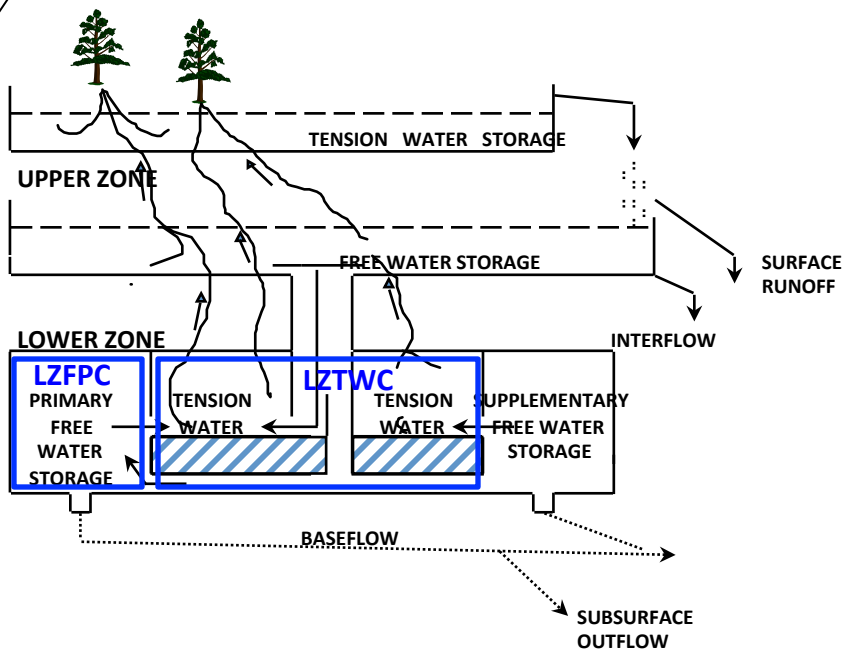
1. Carryover from previous season
2. Affected some by fall precipitation
3. Adjusted by flow observations in fall/early winter

LZTWC (tension water)

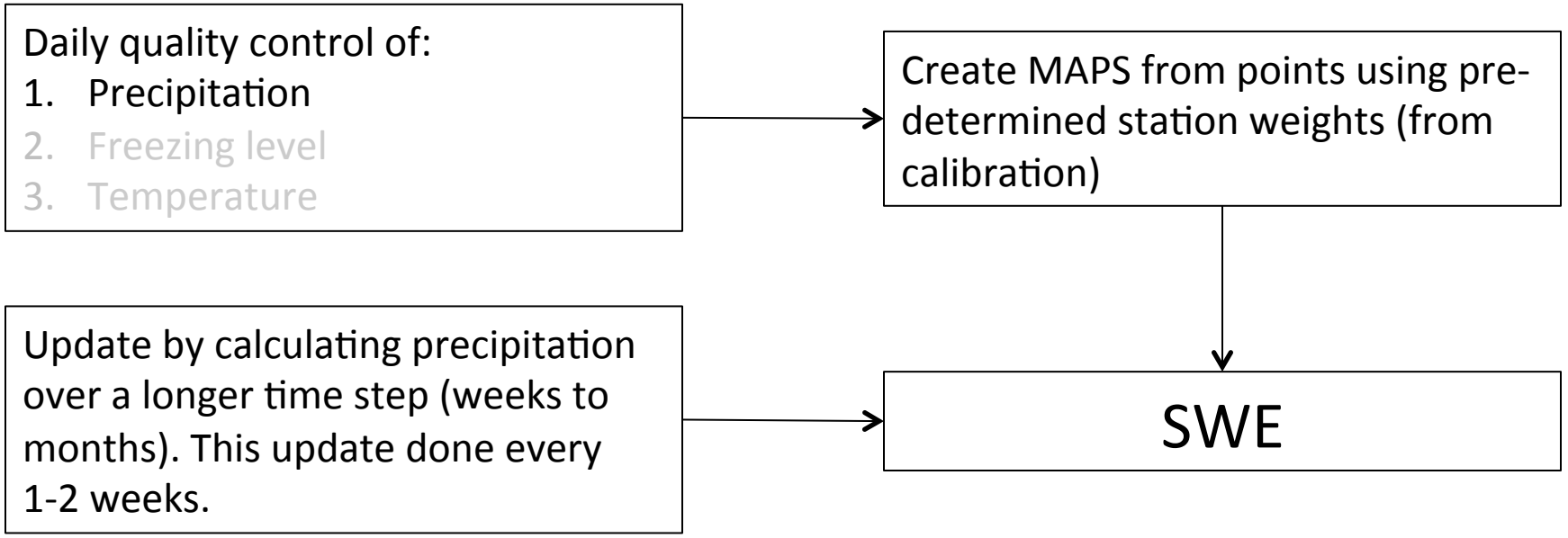
1. Little carryover from previous season
2. Affected strongly by fall precipitation
3. Regionally adjusted

Initial fall soil moisture

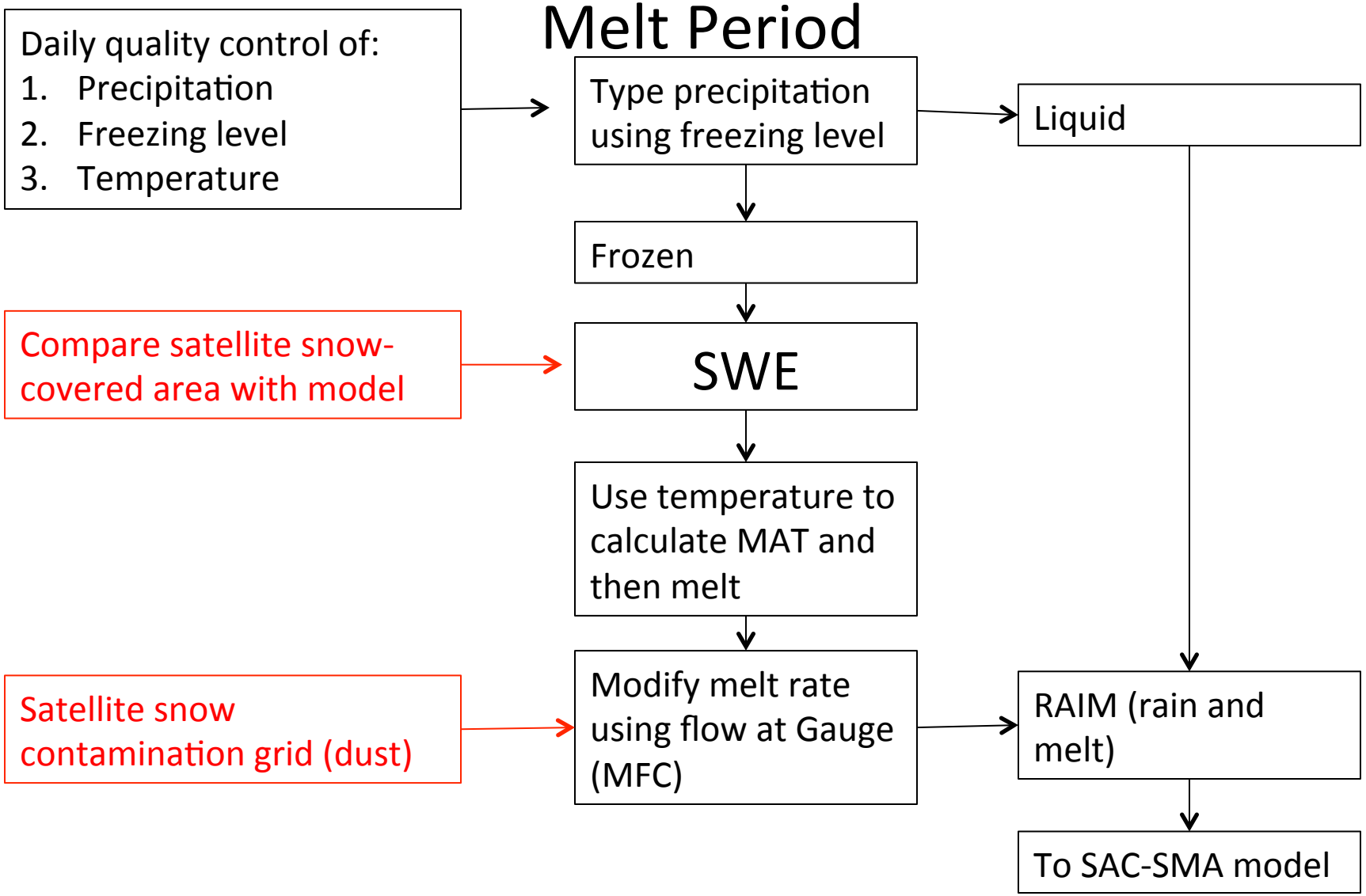
1. Can have a moderate impact on spring runoff (+/- 5-10 %)
2. Typical Capacity of LZTWC +LZFPC ~ 15 inches



Operations
Initial Conditions – SWE
Accumulation Period



Operations
Initial Conditions – SWE
Melt Period

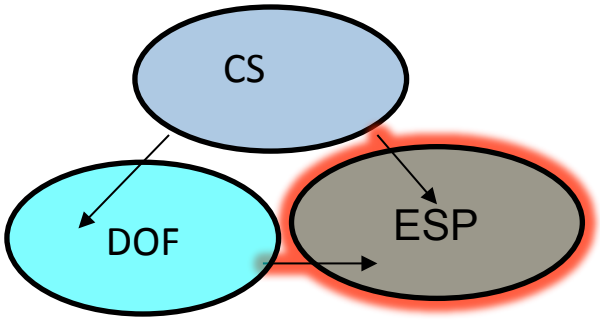


Daily Operational Forecasts

- Regulated (trying to match observed flow in river)
  - Future diversions:
    - Set to current
    - Specified
    - Best guess
  - Future reservoir releases:
    - Set to current
    - Specified (input a schedule)
    - Spill

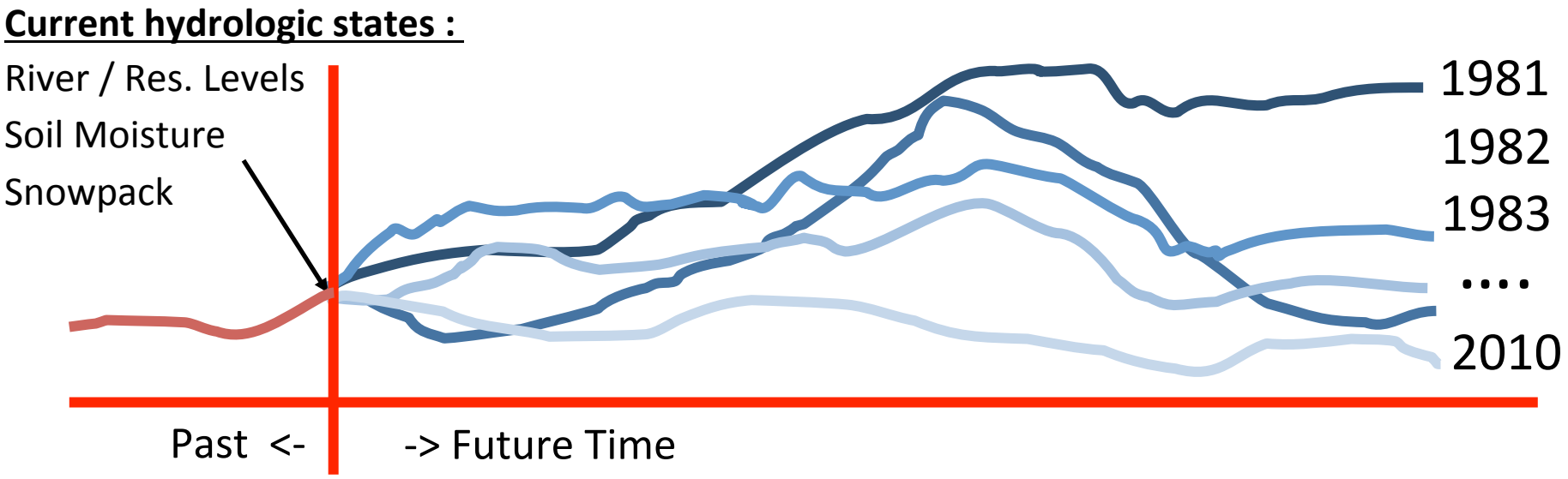
Ensemble Streamflow Prediction (ESP)

- Uses model states from DOF as starting point and can also use forecast precipitation (5 days) and temperature (10 days) inputs
- Uses historical precipitation and temperature time series from CS and statistical distributions to derive probabilistic flow forecasts
- Can adjust output for model bias

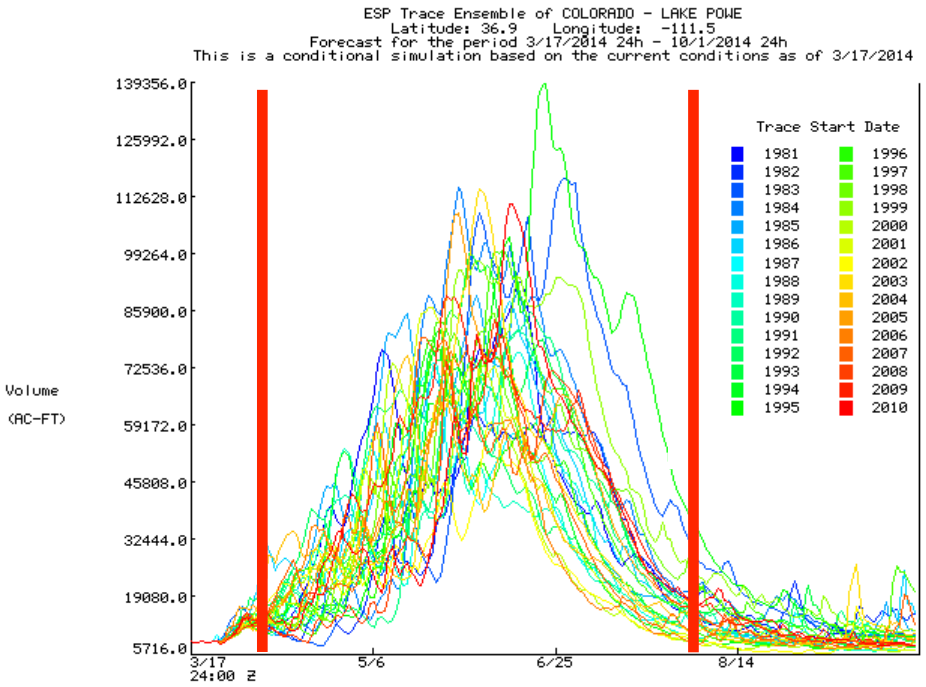


ESP Probabilistic Forecasts

- Start with current conditions (from the daily model run)
- Apply precipitation and temperature from each historical year (1981-2010)
- A forecast is generated for each of the years (1981-2010) *as if, going forward,* that year will happen
- This creates 30 possible future streamflow patterns. Each year is given a 1/30 chance of occurring



ESP Probabilistic Forecasts



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EMPIRICAL SAMPLE POINTS

# Trace year	Cond. Year Weight	Data Point	Exceed. Prob.
1981	0.033	10583427.0	0.290
1982	0.033	8372498.00	0.806
1983	0.033	12646544.0	0.065
1984	0.033	11904022.0	0.129
1985	0.033	11402967.0	0.161
1986	0.033	10406237.0	0.355
1987	0.033	8369501.00	0.839
1988	0.033	8719326.00	0.742
1989	0.033	7605042.50	0.935
1990	0.033	9761623.00	0.452
1991	0.033	9690117.00	0.484
1992	0.033	9298360.00	0.613
1993	0.033	10987106.0	0.226
1994	0.033	9395003.00	0.548
1995	0.033	14388755.0	0.032
1996	0.033	8611564.00	0.774
1997	0.033	10736442.0	0.258
1998	0.033	10159611.0	0.419
1999	0.033	12520652.0	0.097
2000	0.033	8252478.50	0.871
2001	0.033	9312369.00	0.581
2002	0.033	6439105.00	0.968
2003	0.033	9439112.00	0.516
2004	0.033	8867351.00	0.710
2005	0.033	10415361.0	0.323
2006	0.033	8235550.00	0.903
2007	0.033	8964843.00	0.645
2008	0.033	8954274.00	0.677
2009	0.033	11320183.0	0.194
2010	0.033	10185848.0	0.387

2

# Exceedance Probabilities	Conditional Simulation
0.900	8237243.000
0.800	8420311.000
0.700	8893428.000
0.600	9303964.000
0.500	9564614.000
0.400	10175353.000
0.300	10533006.000
0.200	11253565.000
0.100	12458982.000

3

1. The flows are summed into volumes for the period of interest (typically April 1 – July 31)
2. The statistics are simplified
3. 50% exceedance value approximates the most probable forecast

ESP Probabilistic Forecasts

Unregulated Mode

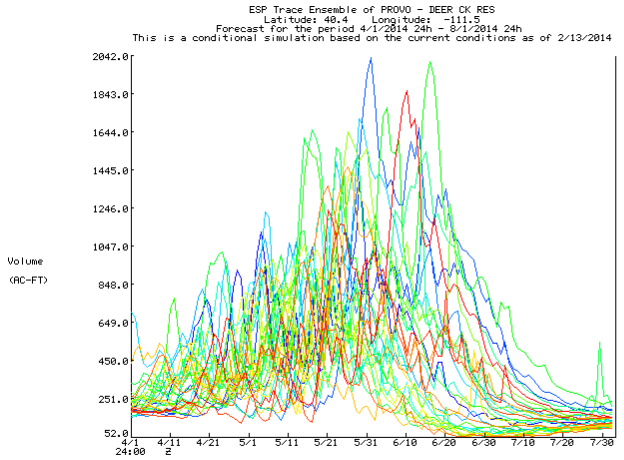
- Reservoirs ignored
  - Water is just passed through them.
- Measured diversions set to zero
  - No water diverted into or out of the basin.
- Unmeasured depletions still removed
- Used for Water Supply volume forecasts
  - Some exceptions in Sevier and Great Basin

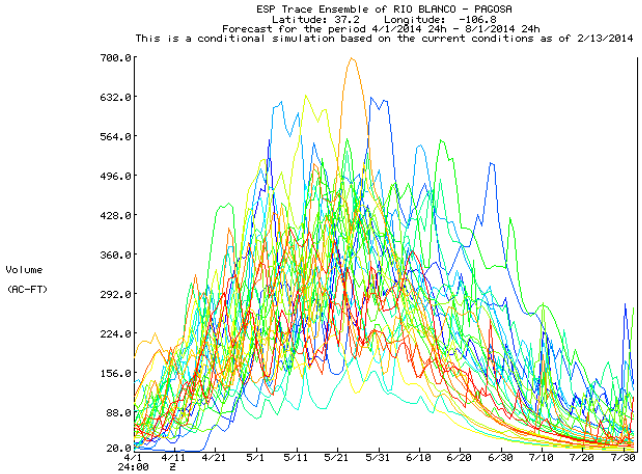
Regulated Mode

- Reservoirs use rules defined in model
  - Releases set based on time of year or simulated elevation of reservoir.
  - Spill, pass flow.
  - Can input a single release schedule if known that far into future.
- Diversions use historical data
  - Trace that uses 1995 MAP/MAT also uses 1995 diversions.
- Unmeasured depletions still removed
- Used mostly for mean daily Peak Flow forecasts

ESP Probabilistic Forecasts

Unregulated Mode

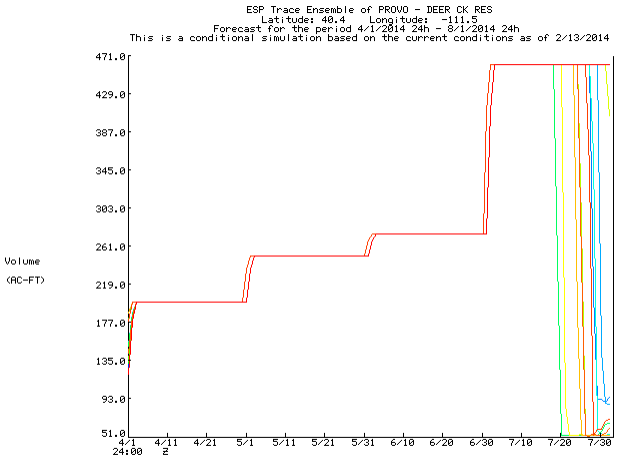


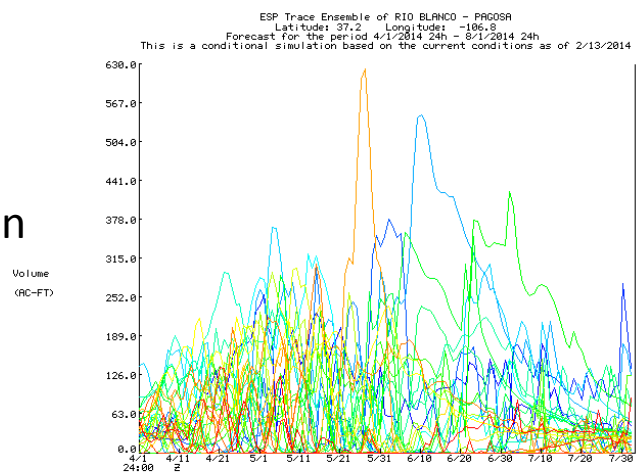


Reservoir

Diversion

Regulated Mode





DOF vs. ESP

Daily Deterministic Forecasts

- Regulated
- INITIAL CONDITIONS ARE VERY IMPORTANT
  - Soil moisture
  - SWE
  - Reservoir elevations/releases
  - Diversions
- Forcings are deterministic
  - Five days of forecast precipitation (QPF)
    - Zero beyond this
  - 10 days of forecast temperature (QTF)
    - Climatological average beyond this
- Creates and saves model states that become starting point for ESP

ESP Probabilistic Forecasts

- Unregulated or Regulated
- INITIAL CONDITIONS ARE VERY IMPORTANT
  - Soil moisture
  - SWE
  - Current reservoir information *not used in unregulated mode*.
  - Diversion data *used in regulated mode only* is from historical years.
- Forcings are probabilistic
  - Uses 30 years of MAP and MAT from calibration to create 30 hydrologic traces/scenarios.
  - QPF and QTF
    - Deterministic QPF (5 days) and QTF (10 days)
    - Can use ensemble QPF and QTF from weather and/or climate models (test mode)